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INCREMENTAL OR ONE-TRIAL LEARNING OF VERBAL SERIES

William H. Sumby

OCTOBER 1965

DECISION SCIENCES LABORATORY
DEPUTY FOR ENGINEERING & TECHNOLOGY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 7682, Task 768201

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FOREWORD

This research was performed at the Decision Sciences Laboratory, Electronic Systems Division, Air Force Systems Command, as part of Project 7682, Man-Computer Information Processing, Task 768201, Data Presentation and Human Data Processing.

This Technical Documentary Report has been reviewed and is approved.

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ABSTRACT

The purpose of this study was to demonstrate that with judicious selection of stimulus material, evidence can be gathered to support either an incremental learning position or an all-or-none position. It is shown that if the a priori response probabilities of words in a series are high, the retrieval of that series from memory will lend support to the all-or-none point of view. If, on the other hand, the a priori probabilities are low, the incremental position will be upheld. It is concluded that learning is incremental, but that high response probability will tend to mask the supporting evidence.
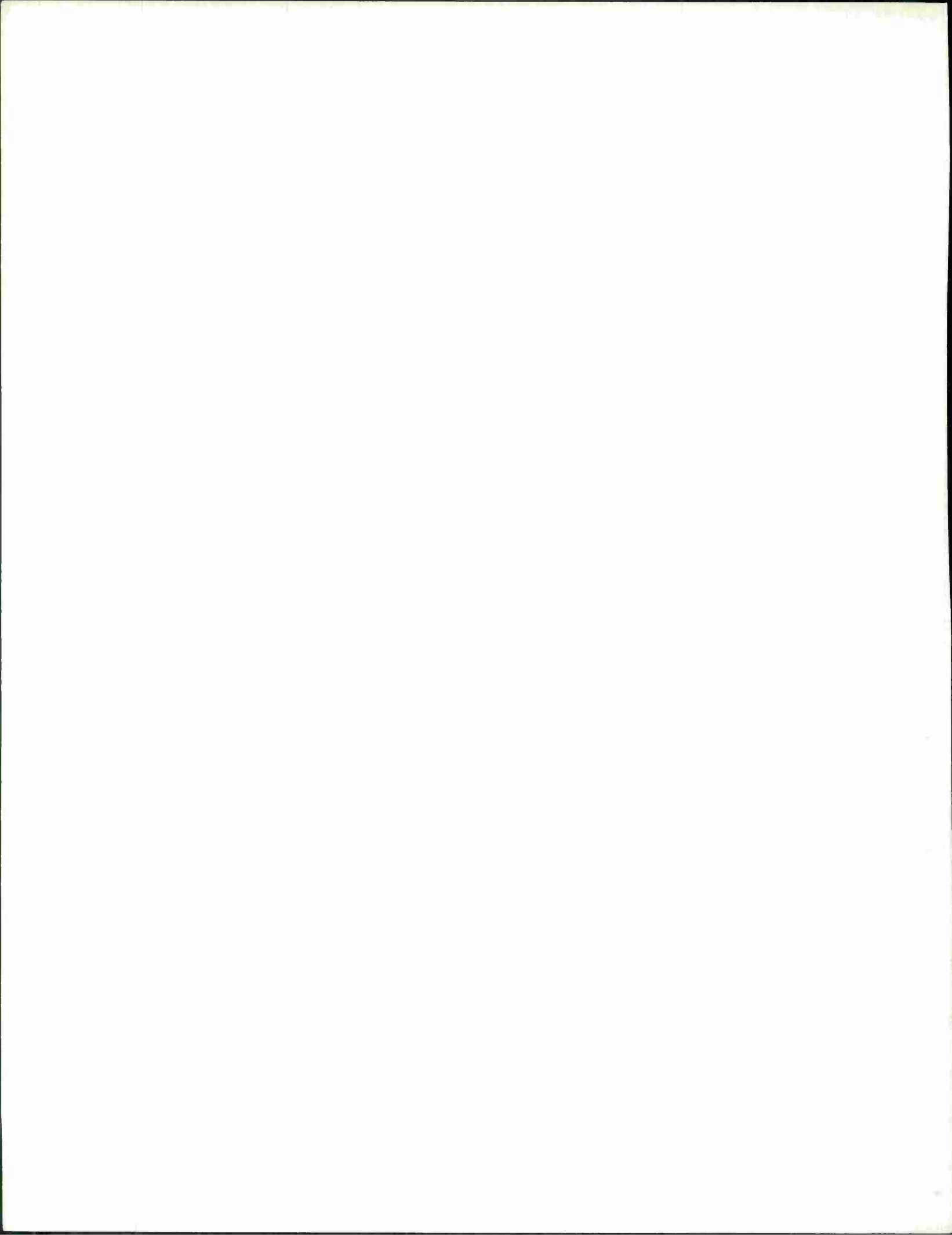
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Introduction

Two major learning theories, one-trial learning and incremental learning, both well documented in the verbal learning literature, generally are considered incompatible. According to the one-trial, or all-or-none position, learning a particular item in a series of items is either complete on a specified trial or no learning occurs at all with that item on that trial. Repetition of item presentation in this case would play no role; the probability of learning a particular item would remain constant from trial to trial. An incremental theory, on the other hand, would maintain that the learning of items is a gradual process. Thus the probability of item recall would increase with item repetition.

The purpose of the experiments to be discussed in the present paper is to effect one possible rapproachement between the all-or-none and incremental positions. Specifically, it is proposed that the probability of item recall does increase with stimulus repetition, but the degree of increase is a function of the a priori response probability, actually the a priori availability of the response in an individual's response repertoire. Here it must be emphasized that an almost undetectable increase in probability is possible. If this proposition should hold, a choice between the two positions will not be forced. Rather, a theory might be framed which to some degree will reconcile the differences between the two supposedly incompatible positions.

First, a recall threshold is posited. Secondly, it is postulated that the learning process will only appear to vary as a function of the distance of a

particular stimulus item from that threshold. It is suggested that the threshold

is approached in measurable increments with stimulus repetition if the

response potential is low as would be the case with infrequently used words.

The probability of recall of a stimulus item will increase with trials. Such

a finding would lend support to an incremental point of view. On the other

hand, it is suggested that if the response potential is initially high, as might

be the case with high-frequency words, the probability of recall of a particular

item will increase in only very small increments, probably not detectable in

many cases, from trial to trial. The response potential would be at or extremely

close to threshold. The probability of recall would be about the same on each

trial, and the resulting data will lend support to an all-or-none position. In

short, it is suggested that the apparent difference in the recall process when

different frequency classes are used as stimuli is a function of the a priori

response potential; the processes of storage and retrieval, it is believed, are

the same for both frequency classes. It is the distance below the threshold

which accounts for the apparent changes in process, and that distance is an

indirect function of the a priori response potential. If the difference is slight

an all-or-none position is supported; if large an incremental position.

It has been demonstrated that the strategy adopted by an individual in

learning a series of words is, to some extent, determined by the relative

frequency of occurrence in the language of the words to be learned (Hall,

1954, and Sumby, 1963). Typically, the shapes of the serial position curves

for the learning of high-frequency and low-frequency words are different,

within limits, (Sumby, 1963). Apparently, the learning rate is slower with

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low-frequency material.   The crucial questions then develop from these facts.   Different learning curves are indicated in the learning of an entire word series as a function of word-frequency.   The questions asked are: 1) is the manner in which an individual item is stored, recognized and retrieved identical over the entire word-frequency range, and 2) is there any evidence that differences between the two theoretical positions are only the results of experimental procedures, specifically stimulus material?

The study was carried out in three phases: 1) recognition of previously presented words, 2) recall of words presented in series with replacement of words correctly retrieved, and 3) recall with a mnemonic device.

Recognition

Method and Procedure

For this experiment 2 groups of 240 monosyllabic, four letter words were assembled: 1) a group of words each having a relative frequency of 400 or above per 4 1/2 million word occurrences, according to the Thorndike-Lorge L count (Thorndike & Lorge, 1944), and 2) a population of words each having a relative frequency below 15 occurrences per 4 1/2 million.   Three series, each of 160 words, were then randomly selected from the two groups: 1) a high-frequency series, 2) low-frequency, and 3) a series made up to an equal number of words from both classes.   The words were presented in one inch letters, one at a time on the scope of a PDP-1 digital computer, each for a period of 1. 5 secs.   Twelve secs. after the 160th word had been presented a second serial presentation contained 80 words included in the

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first list, and 80 words from the same frequency class but not presented

previously. A quasi-random order of "old" and "new" words was arranged

according to the method developed by Nickerson & Brown (1963). The Ss

were instructed prior to the initial presentation that their task was to

determine whether or not each word appearing on the second list had appeared

on the first. The response was made with the on-line typewriter of the

computer. If the S believed that the word shown had been previously presented

the "o" key was pressed. If S believed that the word had not appeared during

the first serial presentation the "n" key was pressed. A response was required

for every word. The computer typed out the results immediately after the 160th

word, indicating the number of accurate responses and the number and the

type of errors made.

For the high series and the low series 8 students from Regis College

for Women participated as paid Ss. Each participated in 2 sessions separated

by one week, one for the high-frequency material and one for the low. Four

were shown the high series first and four the low. Eight additional students

sat for one session of the mixed frequency condition.

This experiment was conducted to determine whether or not any differences

would be revealed between the two word classes in simply getting them into

storage.

Results

The results of the recognition experiment are presented in Table 1.

No statistical difference in the number of "correct" responses is revealed

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Table 1

Percent Correct Responses

for Recognition Task

Word Frequency	Percent Correct
High	78.8
Low	77.4
Mixed	79.0

between any two of the series. In other words, there is no word-frequency effect apparent in the recognition task. The degree of correct recognition is about equal, offering some evidence that the storage process appears to be the same for both classes. Further, any tendencies toward response biases are extremely slight. There is a statistically insignificant tendency under all total conditions to respond "n" more often than "o."

The distribution of types of errors for the mixed-frequency series was not expected. As was pointed out, no difference in the percent correct was revealed between the high series and the low series when presented separately. However, in the mixed series 61.9% of the errors are high-frequency errors. Of these high-frequency errors 60.8% are errors in which S responded "n" when the stimulus was "old." On the other hand, of the low-frequency errors only 41.2% are of that type. Table 2 presents an actual breakdown of the error distribution.

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Table 2

Mean Percent Errors

Recognition Task

Word Frequency	Percent Errors		
	Total	S_oR_n*	S_nR_o*
High	21.2	11.1	10.1
Low	22.6	12.5	10.1
Mixed	21.0	11.2	9.8
Mixed Breakdown			
Total	21.0	11.2	9.8
High	13.0	7.9	5.1
Low	8.0	3.3	4.7

*S_oR_n - Stimulus "o" Response "n"

S_nR_o - Stimulus "n" Response "o"

Recall

Method and Procedure

In the recall experiment the material to be learned was drawn at random from populations of 300 high-frequency and 300 low-frequency, four letter, monosyllabic words. The relative frequency of each of the high-frequency words was above 400 occurrences per 4 1/2 million words and the frequency of each of the low-frequency words was less than 15 occurrences, according to the Lorge Magazine count. This was done in order to maintain some control over the difficulty of recall of the words.

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The words were printed on 3 x 5 white cards in one inch, black letters. A randomly chosen series of 12 words from one of the two frequency categories was shown one at a time at a rate of 1.5 secs. per word. At the end of the series 35 secs. were given to record (on prepared answer sheets) as many of the words as could be recalled. As S wrote the word she also said it aloud. Words which were recalled were withdrawn and replaced by a like number of new words. Words which were not recalled were retained for the next presentation. The combination series of "old" and "new" words was quickly randomized and presented again. A session consisted of 12 trials, i.e., 12 presentations and 12 recalls.

In addition to high- and low-frequency sessions, the same procedure was followed with a series of 6 high- and 6 low-frequency words. The words recalled, after the initial presentation were replaced by members of the same frequency class. It was believed that eventually only a series of low-frequency words would remain. In addition, a modification was introduced in which an entirely new series of 6 high- and 6 low-frequency words was presented for 12 trials in succession.

The Ss were 12 undergraduates of Regis College for Women, working part-time for the Laboratory as subjects and all had previously been exposed to verbal learning tasks. Each S participated in one session of each frequency condition, that is, 3 sessions for each S. The sessions were separated by one week. The order of presentation was counterbalanced.

Results

Initially the recall data were processed simply to determine whether or not the expected difference in recall attributable to word-frequency effect

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held in this experimental situation.   Table 3 indicates that it did; more

Table 3

Mean Number Correct

Recall Task

Word Frequency	Number Correct
High	8.7
Low	7.7
Mixed	9.2
Mixed High	4.5
Mixed Low	4.7

high-frequency words were recalled than low.   The figures shown are the
averages.   The low-frequency words were farther below the posited recall
threshold than the high.   Of particular interest are the findings that more
words were recalled on the average from the mixed-frequency series than
from even the high, and that the number of high- and low-frequency words
recalled in this series was about equal.

When the words in the presented series are from but one class, the
differences between the number of high-frequency words recalled and the
number of low-frequency words recalled is statistically significant at the
.01 level, according to a Wilcoxon Matched Pairs Analysis (Wilcoxon, 1949).
When the analysis was made between the number of high- and low-frequency
words recalled from the mixed presentation with replacement, the recall
difference between classes was not significant.   As a matter of fact, the mean

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number of low-frequency words recalled is slightly greater than the high,

Table 3. When the procedure was modified by presenting an entirely new

series of 12 mixed words on each trial, that is, with no replacement, the

statistical difference between the number of high- and low-frequency words

retrieved was again found to be significant at the .01 level in favor of high-

frequency words.

The results most directly relevant to the major question of the investigation

are shown in Table 4. Table 4 compares the percent words recalled after

Table 4

Percent Correct on Trials

1 and 2 - Recall Task

Trial	Percent Correct		
	High	Low	Mixed
1	76.0	73.2	75.5
2	78.7	80.7	82.4

being shown for the first time with the percent correct of those words shown

for the second time but not recalled on the first. The percent correct for

words appearing for the second time was found to be significantly greater

than words appearing for the first time for both the low- and mixed-frequency

classes, $p < .025$ for both comparisons using a one-tailed Wilcoxon Matched

Pairs test. There is no statistically significant probability difference

between trials for the high-frequency material, although probability of

recall was slightly higher on the second trial. It was not possible to test reliably the differences between subsequent trials because of the paucity of data available after words had appeared twice. The evidence available did indicate that the probability of recall did further increase for the low-frequency material.

Finally, a group of 8 Ss attempted recall of a 12 word mixed-frequency series, half high- and half low-frequency. A different series was presented to each S and the series was presented in a different random order for each of 10 trials. These data were analyzed to arrive at some measure of the stability of the recalled words. The probability that a word recalled on one trial will not be recalled on the succeeding trial is .117 for high-frequency and .123 for low-frequency words. This difference was found not to be statistically significant.

Retrieval with a Mnemonic

Method and Procedure

This experiment involved an attempt to use a task displaying characteristics of both recognition and recall, and possibly a process intermediate between what is typically considered to be a recall and a recognition process. In order to accomplish this a mnemonic device was adopted which appeared to allow the development of a task which could be considered intermediate between the typical recall task and the typical recognition task.

The initial goal was to generate a series of words in which it would be possible to specify grossly the response probability of the words. It is

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possible with many general-type nouns, e.g., fish, trees, etc., to specify the members of the general noun class and thus build up a readily identifiable category. To acquire such series, 48 easily identifiable categories were selected and labeled. Each category label was then read aloud to 100 laboratory personnel and students. They were instructed to respond immediately following the reading of each label with the first member of that category they could think of. Two restrictions were imposed on the response words: 1) a two syllable word was required, and 2) the word could not commonly and logically be placed in any of the other categories, e.g., "orange" - color and fruit.

The responses were tabulated and the word of each category with the highest response frequency was identified as the word of highest response probability. A 48 word series, then, of the high-probability words was compiled, as was a series evidencing low response probability, 1 percent of the responses, but certainly commonly known words, e.g., zebra. A series of words falling between these probability extremes was also formed. In all cases only one word from each category was used.

Each of three groups of 15 Ss was then shown the words of one of the series one word at a time at a rate of 1.5 secs. per word. Different Ss were used for each condition. Immediately after the presentation of the 48th word and in a different order than the order of presentation, the category labels were read aloud. The task was to respond with the category number previously shown after each category label had been read. A 4 second interval was allowed for each response.

Results

The results of the experiment in which a mnemonic device was used in retrieval are presented in Table 5. The average word-frequency of

Table 5

Recall with a Mnemonic Device

Response Probability	Percent Correct	Mean Word Frequency
High	90.0	196.0
Medium	71.7	114.7
Low	58.3	91.4

each probability class is included in the Table. Hall (1954) and Sumby (1963) have demonstrated that differences in frequency of occurrence of the magnitude indicated would not account for the considerable differences shown in response accuracy. No word-frequency effect was apparent within each class; that is, the probability of retrieval using the mnemonic was not influenced by the frequency of occurrence of the word in the language. In addition, the correlation between word-frequency and response probability with classes pooled was only .306. This evidence would suggest that a major source of the variance must be attributable to the response probability of the words rather than frequency effects. Table 5 supports this statement. The number of correct responses increases monotonically with increased response probability.

There is a slight tendency to retrieve successfully fewer words from those categories having large number of alternative response members. Ss were not informed as to the approximate word size of each category, but

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quite probably their own repertoires varied directly with the actual size.

Apparently at times, in an effort to make the appropriate response, Ss

compared their own category repertoire with the perceptual trace of the

stimulus. If S believed an appropriate comparison was made a response

was given. If the category was large necessarily more comparisons would

be made, and the probability of making an appropriate match would decrease

as the size of the alternative set increased. However, since the task is,

in a way, a form of recognition and since response accuracy is typically

extremely high in recognition the results are interesting. If the appropriate

comparison was not made the tendency was to make no response, even

though guessing was not discouraged. In other words, Ss were very much

aware of an inappropriate comparison. For each class approximately 70%

of the failures to supply the appropriate response were omissions and only

30% intrusions.

Discussion

The finding that no difference occurs in the amount of recognition as

a function of word-frequency suggests that the perceptual or storage processes

are not influenced by this variable. A perceptual trace of the words remains

of sufficient strength to allow high and approximately equal recognition

behavior for both frequency classes tested.

The finding that the amount of material recognized does not vary with

word-frequency can be interpreted in one of two ways. It suggests that the

perceptual process is identical for the two word-frequency classes. That is,

the material is stored in the same manner, and that the amount of associative interference which might cause confusion and errors is the same for both high- and low-frequency words although the types of interference might be different. A finding in support of that statement was reported by Sumby (1963). In a learning task in which the words were shuffled after each trial and using free recall, it was found that with high-frequency words the frequent occurrence of words as pairs, regardless of position in the series, tended to be semantic in nature. The low-frequency pairs, on the other hand, tended to associate phonetically, but to a degree equal to the high-frequency associations. A second explanation based on a study by Gorman (1961) offers evidence in support of greater associative potential being developed between the high-frequency words than the low which would cause more interference between high-frequency words and thus reduce any differences. Gorman's results suggest that the associative potential of high-frequency words might tend to mask a frequency effect in recognition. However, since learning is considered to be a process of acquisition, only measurable by retrieval, the point to be made is that certainly some learning did take place during the stimulus presentation as evidenced by the degree of correct recognition in the first study reported. When the Ss were asked to recall as many of the words as possible after the recognition phase, the recall scores (all words had been seen once, half twice) were significantly lower than the recognition scores. In other words, the response potential of these words had not reached the threshold of recall, even though a perceptual trace was demonstrated to be present by the fact that the words could be recognized as having been presented.

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When the task was only recall of words as a function of word-frequency the difference between frequency classes was made apparent. High-frequency words are recalled more frequently than are low when the words in the series are homogeneous with respect to word-frequency. Again, since the probability of a perceptual trace of sufficient strength for recognition is present, and since the difference in recall occurs, we must again assume that the difference can be attributed to the response potential of the word. That the response potential increases with stimulus repetition is clearly shown with the low-frequency material. The probability that recall will be accomplished after the second presentation is higher than after the first for this frequency class. No difference is evidenced between the first two trials with high-frequency material which suggests that the words are closer to the threshold of recall and the learning increment is not detectable. Those supporting the all-or-none theory would have difficulty in explaining the probability difference between trials for the low-frequency series since they would contend that actually a new series was presented each time, and recall probably would be the same with each trial. The theorists who favor an incremental position would have difficulty demonstrating that position with the high-frequency results.

When a mnemonic device is introduced, again word-frequency differences appear to have little effect on the retrieval. It appears that a major source of the variance is the response probability of the words and not word-frequency per se. If the response probability is high the probability of retrieval is high regardless of word-frequency.

These three experiments present some evidence that the incremental and the all-or-none theories of learning are not mutually exclusive. It appears that the storage or recognition of materials varying in word-frequency is identical over the entire frequency range. Recognition does not vary as a function of word-frequency. It might be concluded at first glance that, indeed, recall is a function of word-frequency per se. However, the data indicate that a priori response probability is the major factor. Since the response probability of high-frequency words is typically, but not always, greater than low-frequency words, recall of the high-frequency tends to be greater in a straight recall experiment. However, when response probability is systematically manipulated and word-frequency average and range held relatively constant among word series, the number of appropriate responses increases with the response probability.

Since perceptual traces of previously presented stimuli allow for a high degree of recognition independent of word-frequency, it must be concluded that some acquisition has occurred for all words even though recall is not possible after one trial. However, since recall is greater for those words evidencing a high response probability it can be said that the response potential is stronger for those words. If, then, repetition increases the response potential and thus response probability for words initially low in such probability, it follows that such words would have a greater probability of recall on succeeding trials. Since probability of recall does increase on succeeding trials with low-frequency words, and

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not apparently with high-frequency words, the following conclusion is reached: learning is an incremental process which is apparent with certain types of stimulus material and completely masked by others. If the stimulus material is initially well below response threshold an incremental increase in probability of responding is revealed. If the material is close to threshold, little, if any, incremental change is evidenced.

Summary

The purpose of this study was to demonstrate that with judicious selection of stimulus material, evidence can be gathered to support either an incremental learning position or an all-or-none position. It is shown that if the a priori response probabilities of words in a series are high, the retrieval of that series from memory will lend support to the all-or-none point of view. If, on the other hand, the a priori probabilities are low, the incremental position will be upheld. It is concluded that learning is incremental, but that high response probability will tend to mask the supporting evidence.

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